ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 6-1
SPMEA 741

30 April 1945

1. PROJECT: No. 6-1 - Determination of the Visual Requirements for Various Tasks in Armored Vehicles; Subject: Study of Errors in Range Estimation with the Unaided Eye.

a. Authority: Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.[illegible]/6 GNOHD, dated September 24, 1942.

b. Purpose: To study the accuracy of range estimation without visual aids among tank crew trainees with special reference to (1) degree of accuracy obtained, (2) possibility of preselection of the more competent individuals, (3) improvement with training, and (4) influence of the character of targets and terrain.

2. DISCUSSION:

a. Range estimation is one of the most important and, at the same time, least accurate element in tank gunnery. Previous studies of visual range estimation performance have dealt with the average proficiency or lack of it in groups of soldiers, the burden of the investigations being concerned primarily with the magnitude of the mean errors, and the influence of the distance of the target on the accuracy of its estimate. In substance, however, the outstanding finding has been that troops in general do not estimate ranges accurately enough to secure hits with the first round of fire, and that the errors, being of the order of 20% or more, necessitate bracketing with several rounds, before the target is struck. It seemed desirable, therefore, to inquire more fully into the measures that might be adopted to improve this situation. Such measures might be:

(1) The incorporation of range finders as standard equipment for tanks. At the present time there are none in American tanks in combat theatres and the current opinion is that the time required to remove the range finder from its stowage, mount it, and use it, is not frequently available in combat. New types of range finders are, however, under consideration for limited issue, but it is generally agreed that the tactical, lighting, and terrain conditions are not always suitable for their use. Furthermore, special training may be a complicating requisite for their effective employment.

(2) Calculation of distance from the angle subtended by the target on a mil scale. For this to be done accurately, the optical instrument must be stable, as would be the case with the tank telescope if the tank were stationary, but not with binoculars;

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and the size of the target must be known. Time is required for the calculation; and, more important, the precise target size will not be generally known.

(3) Intensive training of tank crewmen in estimation with the unaided eye. As pointed out above, studies of the performance of men have generally indicated relatively imperfect performance. One may therefore raise these questions:

(a) Can the technique of instruction be improved, with consequent reduction in the error of estimate?

(b) Would more intensive instruction of tank crewmen produce better results? (A recent AORG report, No. 225 on The Accuracy of Visual Estimation of Initial Range... concludes that "...an improvement in performance by the NCO category of personnel is possible by continuous training and practice in range estimation".)

(c) Should tank crewmen, or more particularly tank commanders and gunners, be selected for their proved or potentially superior capabilities in range estimation? (The antiaircraft and coast artillery commands devote several weeks to training on height and range finders, of men preselected for their intelligence and the excellence of their vision.)

b. The range estimation records of a large group of men for 32 targets on three different ranges were obtained for study from the gunnery department of the ARTC. This analysis undertaken to evaluate from these records five aspects of the range estimation problem:

(1) The general level of competence of men in training as tank crewmen.

(2) The level of excellence of the 10 most capable men of the group.

(3) The degree of improvement with training.

(4) The relationship of general vision and of previous civilian experience to accuracy in judging distance.

(5) The influence of the character of the target on the estimate of its distance.

3. CONCLUSIONS:

a. The mean error for all 4472 estimates was 26.6%. This was considerably higher than the median error of 20% for the reason that one-sixth of all estimates were in error by more than 40%. On the other hand, slightly less than one-third of all estimates were exceptionally good, being incorrect by less than 10%.

b. Some men possess outstanding skill in estimating distances. There were 10 men in the present group whose median error for 32 separate range estimates was 13% or less, the best having a median error of only 8%. These men had had only several weeks basic military training prior to this test.

c. The failure of the group as a whole to improve in successive exercises suggests that the technique and extent of instruction does not substantially increase the range estimation proficiency of trainees.

d. The best and poorest range estimators of this and of another group of men, specially examined, could not be distinguished on the bases of civilian occupation, participation in outdoor sport, urban or rural residence, or vision tests.

e. The tendency to underestimate the distance to targets with sharp, well-defined contours was consistent. Examples of such targets were: vehicles, coniferous trees, and range limit markers. The targets most frequently overestimated were partly hidden objects and those with low contrast. Neither the target's azimuth nor distance up to 1600 yards appeared to influence the pattern of error.

4. RECOMMENDATIONS:

a. That identification of the more competent range estimators be regarded as an important consideration in the selection of tank commanders and gunners.

b. That the reasons for the apparent superiority in range estimation possessed by some individuals be further investigated as a basis for improving range estimation instruction generally.

c. That improved devices and techniques for range estimation instruction be sought.

d. That the influence of the character of the target be pointed out in imparting range estimation instruction to men. In particular, the tendency to underestimate the distance to targets of sharp outline should be appreciated. This may be of importance when fire is directed at a terrain feature which is selected because of its inferred proximity to an enemy strongpoint.

e. That investigation and development of built-in tank range finder be continued.

NOTE: The recommendations as set forth in this project have been concurred in by Col. Fred W. Makinney, Chief of Staff, Armored Center.

Submitted by:
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4 Incls.
#1 - Appendix I
#2 - Appendix II
#3 - Appendix III
#4 - Figures 1, 2 and 3a to 3p

APPROVED Willard Machle
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Commanding

APPENDIX I

ACCURACY OF RANGE ESTIMATION

1. Introductory.

a. The present study of accuracy of direct range estimation with the unaided eye makes use of data obtained from troops in the gunnery section of basic training at the Armored Replacement Training Center. There were 32 targets in all, and on these a total of 4472 separate estimates were made. The 32 targets were on 3 ranges, each range being employed in a separate exercise.

Range #1 - Within the barracks area of the Post—10 targets, approximately 175 men participating.

Range #2 - On Steele's Firing Range #4—in open country—10 targets—approximately the same 175 men.

Range #3 - On Steele's Firing Range #3—in open country—12 targets—approximately 95 of the original 175 men.

b. Ranges are routinely estimated by the men in groups of 10 to 20, as part of their gunnery instruction course, under the supervision of an officer or NCO. For each range, the individual is given a blank form on which he is instructed to write a one-word description of the target, and his estimate of the distance in yards after the target is pointed out to him by the instructor. He is permitted to identify the target with binoculars, but the distance estimate is made with the unaided eye. At the termination of the exercise the men are told the correct range to each target and they then compute their scores. It is of interest that although the program is intended for instruction, it is generally conducted more in the manner of an examination, with no clues given by the instructors until the estimates have been made.

2. Performance of the Group as a Whole.

a. Figure 1 gives the overall accuracy of all the estimates. Fewer than a third were within 10% of the true range; approximately one-half were within 20% of the correct distance; and one-sixth were more than 40% in error. The mean error was 26.6%, and the median error was 20%. Since this is the only range estimation practice which many of these men receive before going overseas as replacements, it would seem that they had not developed their skill to a high point of excellence.

b. Of the entire group, 86 of the men estimated the distances to all 32 targets. The distribution of the median estimation errors of these men is shown in Figure 2. For this group the mean error without regard to sign was 26.0% with a standard deviation of ± 12.5% and a probable error of the mean of ± .91%.

3. Performance of Superior Individuals.

Many of the scores in the group of 86 men indicated highly superior ability

in range estimation. The best individual estimated all 32 targets with a median error of 8% and a mean of 12.3%. The median error for the best 10 men of this group was 13% or less. Table 1 gives the individual scores of these 10 men, together with a partial tabulation of the magnitude of their errors on all the targets. These are compared in the same table with the performance of the 10 poorest performers.

TABLE 1

THE PERFORMANCE OF THE 10 BEST AND 10 POOREST RANGE ESTIMATORS ON 32 TARGETS

Name	Median % Error	Arithmetic Mean % Error	No. Estimates Accurate Within 10%	No. Estimates In Error By 50% or more
BEST				
1. E.J.G.	8	12.3	19	0
2. H.J.S.	9.5	13.2	16	1
3. F.R.J.	10	14.4	15	0
4. T.F.B.	10	17.5	12	2
5. W.A.D.	10.5	12.7	15	0
6. W.A.B.	11	18.5	12	2
7. J.L.S.	12	14.2	14	1
8. W.J.K.	12	19.9	14	4
9. R.R.H.	12.5	19.6	13	2
10. R.F.K.	13	16.6	11	1
POOREST				
1. J.I.D.	39.5	101.9	6	12
2. A.A.S.	34.5	35.5	3	6
3. H.E.T.	33	29.3	9	9
4. J.A.Z.	32	43.0	5	10
5. R.K.	31.5	30.0	6	4
6. H.L.C	31	40.6	3	9
7. G.C.B.	29	32.1	7	7
8. D.E.M.	28.5	46.8	5	11
9. R.G.M.	28.5	30.3	6	7
10. M.C.B.	28	29.6	6	5
(FOR COMPARISON) ALL MEN	20	26.6		

Incl. #1

4. Influence of Training.

a. The target distances on Range #1, #2 and #3 were estimated in that order with intervals of a few days between exercises. The scores indicate that the men did not improve in their performance on the successive ranges, but actually tended to do more poorly and accordingly did not profit from their instruction.

TABLE 2

PERCENT OF ACCURATE ESTIMATES AND MEAN ERROR BY RANGES

	% of Estimates Accurate within 10%	Mean Error of all men
Range #1	40.2%	18.3%
Range #2	26.2%	31.9%
Range #3	22.6%	27.6%
ALL TARGETS		26.6%

b. The targets and locale of Range #1 were undoubtedly more familiar to the men than those on Range #2 and #3, since Range #1 is in the urban part of the Post, and Ranges #2 and #3 are in open country. This resulted in relatively greater accuracy of range estimation on Range #1 (Table 3). The targets on Ranges #2 and #3, on the other hand, were approximately equal with regard to difficulty of range estimation, as shown in Table 3, wherein it is noted that the number of men making better scores on one of these two ranges is approximately equal to the number of men making better scores on the other.

TABLE 3

COMPARATIVE DISTRIBUTION OF THE MEAN ESTIMATION ERRORS OF 86 MEN FOR THE 3 RANGES ON WHICH THEY WERE SUCCESSIVELY TESTED AT ABOUT 3-DAY INTERVALS

	NUMBER OF MEN	
Lower Mean Errors on Range #3 as compared with Range #2	40	
Higher " " " Range #3 " " " Range #2	45	
No difference in Mean Errors on Range #3 as compared with Range #2	1	
		86
Lower Mean Errors on Range #2 as compared with Range #1	29	
Higher " " " Range #2 " " " Range #1	57	
		86
Lower Mean Errors on Range #3 as compared with Range #1	23	
Higher " " " Range #3 " " " Range #1	63	
		86

NOTE - Range #1 in urban part of Post
Ranges #2 and #3 in open country on firing ranges

APPENDIX II

CONSIDERATIONS RELATIVE TO PRESELECTION

1. Civilian Occupation and Residence.

The men at the Replacement Center whose range estimates formed the basis of this study had gone overseas by the time analysis of the data was completed. Consequently, it was not possible to interview or further examine them to discover any attributes which might be responsible for the performance of the best and poorest individuals. The only information available was with regard to place of residence and civilian occupation, which, as indicated in Table 4, does not appear to offer any basis for distinguishing between the superior and poorer groups.

TABLE 4

CIVILIAN OCCUPATION AND RESIDENCE OF TEN BEST AND TEN POOREST RANGE ESTIMATORS

Name	Civilian Occupation	Civilian Residence
BEST		
E.J.G.	Farmer	Rural Wis.
H.J.S.	None	" Mont.
F.R.J.	Farmer	" Wis.
T.F.B.	Mill Worker	Urban Mich.
W.A.D.	Laborer	" S. C.
W.A.B.	Mechanic	" Mich.
J.L.S.	Electrician	" Florida
W.J.K.	Clerk	" Wis.
R.R.H.	Clerk	" S. C.
R.F.K.	Mechanic	" Ill.
POOREST		
J.I.D.	Farmer	Rural Wis.
A.A.S.	Farmer	" Mich.
H.E.T.	Miner	" Mont.
J.A.Z.	No record	-
R.K.	No record	-
H.L.C.	Farmer	" Mo.
G.O.B.	Clerk	Urban O.
D.E.M.	Farmer	Rural Mo.
R.G.M.	Laborer	" Ill.
M.C.B.	Mechanic	Urban Ill.

2. Vision and Participation in Sport.

a. Accordingly more extensive examinations were made on other similar classes of men from the ARTC. The ten best and the ten poorest range estimators of two classes were given vision tests with the Keystone Telebinocular, and the ten best and ten poorest of one class were questioned regarding civilian occupations and hobbies. The eye tests included examinations for acuity, astigmatism, binocular fusion and heterphoria, stereopsis, and color vision. The results of these tests may be summarized as follows:

Of the 20 best range estimators:

15 men had completely satisfactory vision
1 man was color blind
1 man had moderately diminished visual acuity
3 men had multiple vision defects

Of the 20 poorest range estimators:

12 men had completely satisfactory vision
2 men were color blind
2 men were astigmatic
4 men had multiple vision defects;

b. In view of the similarity between these two groups, it seems that neither the possession of normal vision nor the existence of visual defects determined the range estimating ability of this group of men.

c. Of the 10 best range estimators who were questioned concerning civilian sports activities:

4 men were farmers and had hunted extensively
4 men had lived in the country but had hunted little
2 men were city dwellers with no hunting or golf expereince

Of the 10 poorest range estimators so questioned:

5 men were farmers and had hunted extensively
2 men had lived in the country but had hunted little
3 men were city dwellers with no hunting or golf experience

d. It seems unlikely from these comparisons that previous civilian experience exerts a consistent influence on range estimating ability, although some men who may have been surveyors, hunters, or golfers, undoubtedly do profit by these activities.

e. By exclusion, the inference seems to be that judgment of distance is a special skill which is either inherent or can be learned through diligent application; that it may not be much impaired by moderate vision defects; and that no method is apparent as yet for selecting in advance of actual trial, those individuals whose performance is likely to be superior to that of other men.

APPENDIX III

INFLUENCE OF CHARACTER OF TARGET AND TERRAIN

1. Certain factors which may conceivably influence the accuracy of range estimates are those related to the nature of the target and its surrounds, including illumination and contrast.

a. In this regard instructions in the Basic Field Manual, U. S. Carbine, Caliber .30 M, FM 23-7 state that:

Objects seem nearer:

(1) When the object is in bright light;
(2) When contrast is sharp;
(3) When the line of sight is over a uniform surface;
(4) When the line of sight is downward;
(5) When looking over a depression most of which is hidden;

Objects seem more distant:

(1) When looking over a depression most of which is visible;
(2) When there is poor light or fog;
(3) When only a small part of the object can be seen;
(4) When the line of sight is upward from low ground;

b. An analysis of the estimates on the 32 targets confirms the principles outlined above, to the extent possible in a study of this limited extent. In most instances the errors in estimating the distances to targets which were clearly seen and sharply outlined were characteristically underestimates. Conversely, some of the targets which were overestimated presented indistinct outlines. However, neither the targets most frequently estimated correctly (i.e. within 10%), nor those with no consistent pattern of error, possessed attributes in common to suggest an explanation for the pattern of the distance estimates.

c. Table 5 gives a description of the 32 targets, with their distances and azimuths, the percentage of accurate estimates, and the percentage of inaccurate estimates, partitioned for over- and underestimation.

TABLE 5

DESCRIPTION OF TARGETS
ARRANGED IN ORDER OF DECREASING PERCENTAGE OF UNDERESTIMATES

RANGE #1 - Urban Area of Fort Knox; Observation Point on Knoll.
RANGE #2 - Firing Range in Rolling Country; Observation Point, Top of Slight Rise.
RANGE #3 - Firing Range in Partially Cleared Rolling Country; Observation Point in Flat Clearing.

(Correct estimates are those within 10% of true range; erroneous estimates are those more than 10% in error.)

Range No.	Target No.	Description	Distance Yds.	Azimuth	Remarks	% Correct Estimates	% Erroneous Estimates	
							over	short
3	4	Range marker	365	E	Sharply outlined, brightly striped.	16	9	75
2	3	Trunk of dead tree	699	NNE	Framed by clearing in woods, but beyond the woods.	18	11	71
3	11	Jeep near small shed	149	W	Sharply outlined.	12	17	70
3	6	Range marker	653	SE	Sharply outlined, brightly striped.	23	13	63
1	2	Large lone oak tree	710	NNE	On upward slope of clearing.	39	4	57
2	6	Pile scrap metal	543	ENE	Below horizontal line of sight—no obstruction to vision.	23	21	56
3	1	Lone pine tree	526	NNE	Up gradual slope toward horizon.	15	30	53
2	7	Jeep body	333	E	Clearly seen—contrast low.	24	24	52
3	3	Broken truck body	1045	ENE	Top of body visible through brush—dead ground intervening beyond crest of upward slope.	24	25	50

TABLE 5 (cont'd)

Range No.	Target No.	Description	Distance Yds.	Azimuth	Remarks	% Correct Estimates	% Erroneous Estimates	
							over	short
1	4	Corner of large bldg.	513	ENE	Sighted downward, no obstruction.	31	19	49
3	8	Jeep under cedar tree	495	WSW	Tree symmetrical and sharply outlined.	23	28	48
1	1	Barracks bldg.	843	N	Among trees, elevated above group of barracks in hollow.	39	18	43
2	2	Broken down truck	456	ENE	Incompletely seen due to irregular ground.	29	29	42
2	10	Small shed	775	ESE	Seen through trees near permanently located tanks.	28	32	42
3	9	Black truck	603	W	Seen across hollow partly obstructed by brush.	27	31	41
2	4	Rusty broken down truck	732	NNE	Incompletely seen due to irregular ground.	26	34	40
3	7	Telephone pole	702	SW	Low contrast. Against woods.	20	39	40
2	8	Truck body	922	E	Partly hidden by foliage—indistinct—contrast very low.	27	37	36
1	6	Corner of barracks	558	S	Sighted over high coal piles.	35	29	36
2	9	Safety marker	805	E	Brightly striped—but seen on edge.	33	32	35
3	2	Broken truck body	785	NE	Little more than cab visible due to brush, terrain irregularity and low contrast.	28	37	34

TABLE 5 (cont'd)

Range No.	Target No.	Description	Distance Yds.	Azimuth	Remarks	% Correct Estimates	% Erroneous Estimates	
							over	short
3	5	Battered truck body	825	ESE	Obscured by brush. Contrast low.	33	34	32
1	9	Corner bldg.	850	W	Only part of bldg. visible along paved street.	45	23	32
3	10	Battered peep	630	W	Obscured by brush and low contrast.	22	45	31
2	1	Cedar tree—symmetrical	117	N	On slightly higher ground than O.P. with moderate depression intervening—seen against sky.	12	58	30
3	12	Badly battered peep	1880	WSW	On eroded slope across broad ravine.	28	44	27
2	5	Bare spot on distant ridge	1760	NE	No specific object as target. Distance is an even mile.	42	32	25
1	10	Barracks	840	NNW	On eminence partly hidden by trees.	63	14	23
1	3	Truck body with no wheels	831	NE	On upward slope of grass covered clearing —outline sharp.	53	33	13
1	5	One room bldg.	635	E	Along straight paved road.	30	59	11
1	7	Corner large bldg.	325	WSW	Lone bldg. on hill—sighted upward against sky.	30	60	9
1	8	Upper eaves of bldg.	371	W	Only upper corner of bldg. visible along paved street.	37	56	6

d. Arranged in similar order, Figure 3, a to p, shows graphically the distribution of errors on these targets. On 7 of them, 35% or more of the estimates were within 10% of the true range. Six of these were on the first range, which together with the lower average error on this range suggests that targets in urban areas present less difficulty than those in open country. There was a tendency to underestimate the distances on 19 targets, to overestimate on 8, while on 5, although the errors were numerous, no patter of error was discernible. Table 6 lists those targets which were most strikingly over- or underestimated, and presents the predominant character of error on them for all the men, and for the 10 best men. Since the errors of both groups of men is in the same direction on both sets of targets, the impression is gained that the type of error is a function of the target rather than of the individuals doing the estimating. Nor did it appear that the pattern of error for any one man was characteristically over or short.

e. These observations might be applicable to specific combat situations confronting armored crews. When the range must be estimated to a terrain feature in the vicinity of which an enemy strongpoint is suspected, the estimate is very likely to be more than 10% short if the object is one which has sharp outlines. If the target be a vehicle, or a tree, for example, its distance will tend to be underestimated if its contours are sharp, and overestimated if only part of it is seen, and that indistinctly.

TABLE 6

COMPARISON OF PERFORMANCE OF ALL MEN WITH THAT OF 10 BEST MEN ON SELECTED TARGETS.

Range No.	Target No.	Targets Consistently Underestimated	Errors of all men*			Errors of best 10 men*	
			% of Total	% Over	% Under	No. of men over	No. of men under
3	4	Range marker, 365 yds.	84	9	75	0	5
2	3	Trunk of dead tree in clearing, 699 yds.	82	11	71	0	4
3	11	Jeep at close range, 149 yds.	77	17	70	0	6
3	6	Range marker, 653 yds.	76	13	63	0	2
1	2	Large lone oak, 710 yds.	61	4	57	0	3
2	6	Pile of scrap metal in field, 543 yds.	77	21	56	1	4
		Targets Consistently Overestimated					
1	8	Upper front part of bldg. visible along street, 371 yds.	62	56	6	5	1
1	7	Corner large bldg. on hill, 325 yds.	69	60	9	4	1
1	5	Shed visible at end of street, 635 yds.	70	59	11	5	0

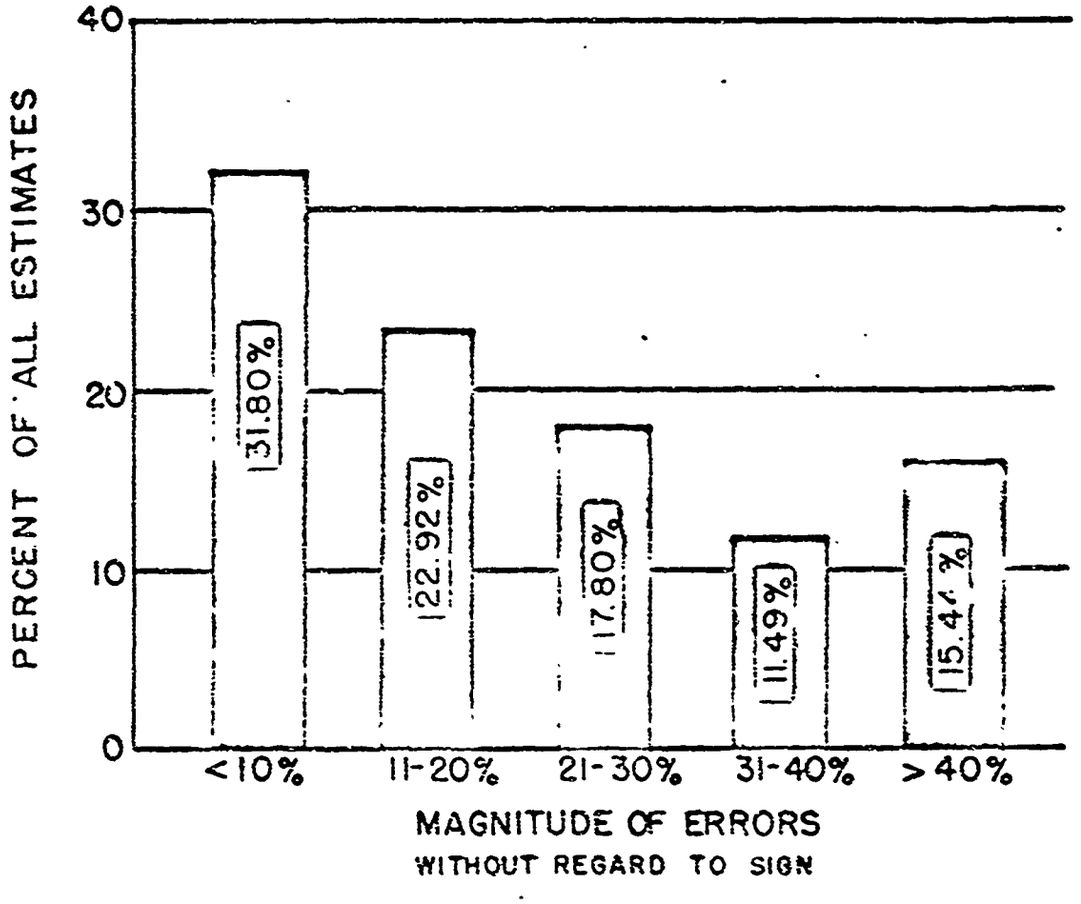
* Differing from true range by more than 10%

FIG. 1.

DISTRIBUTION OF 4472 RANGE ESTIMATES MADE BY TRAINEES IN GUNNERY AT THE A.R.T.C.

(a) 20 TARGETS ON 2 RANGES ESTIMATED BY ALL MEN.

(b) AN ADDITIONAL 12 TARGETS ON A 3 RD. RANGE ESTIMATED BY HALF THE MEN.



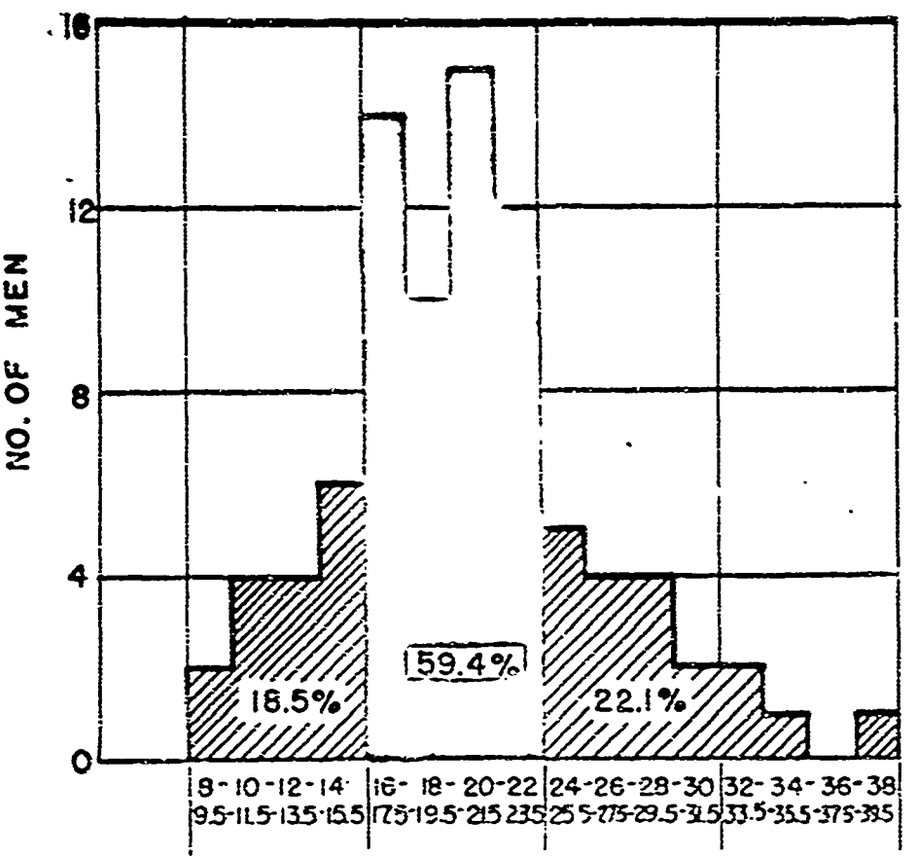
Incl. #4

FIG.1

FIG. 2

MEDIAN RANGE ESTIMATION ERRORS OF 86 INEXPERIENCED GUNNERY TRAINEES AT A.R.T.C.

(32 TARGETS ON 3 RANGES)



MEDIAN % ERROR FOR 32 ESTIMATES.

WITHOUT REGARD TO SIGN

Incl. A

FIG. 2

FIG. 3 A-P
DESTRIBUTION OF RANGE ESTIMATION ERRORS FOR EACH TARGET.

INDICATING BOTH THE DIRECTION AND MAGNITUDE OF ERROR.

THE CHARTS ARE ARRANGED IN THE SAME ORDER AS IN TABLE 5.

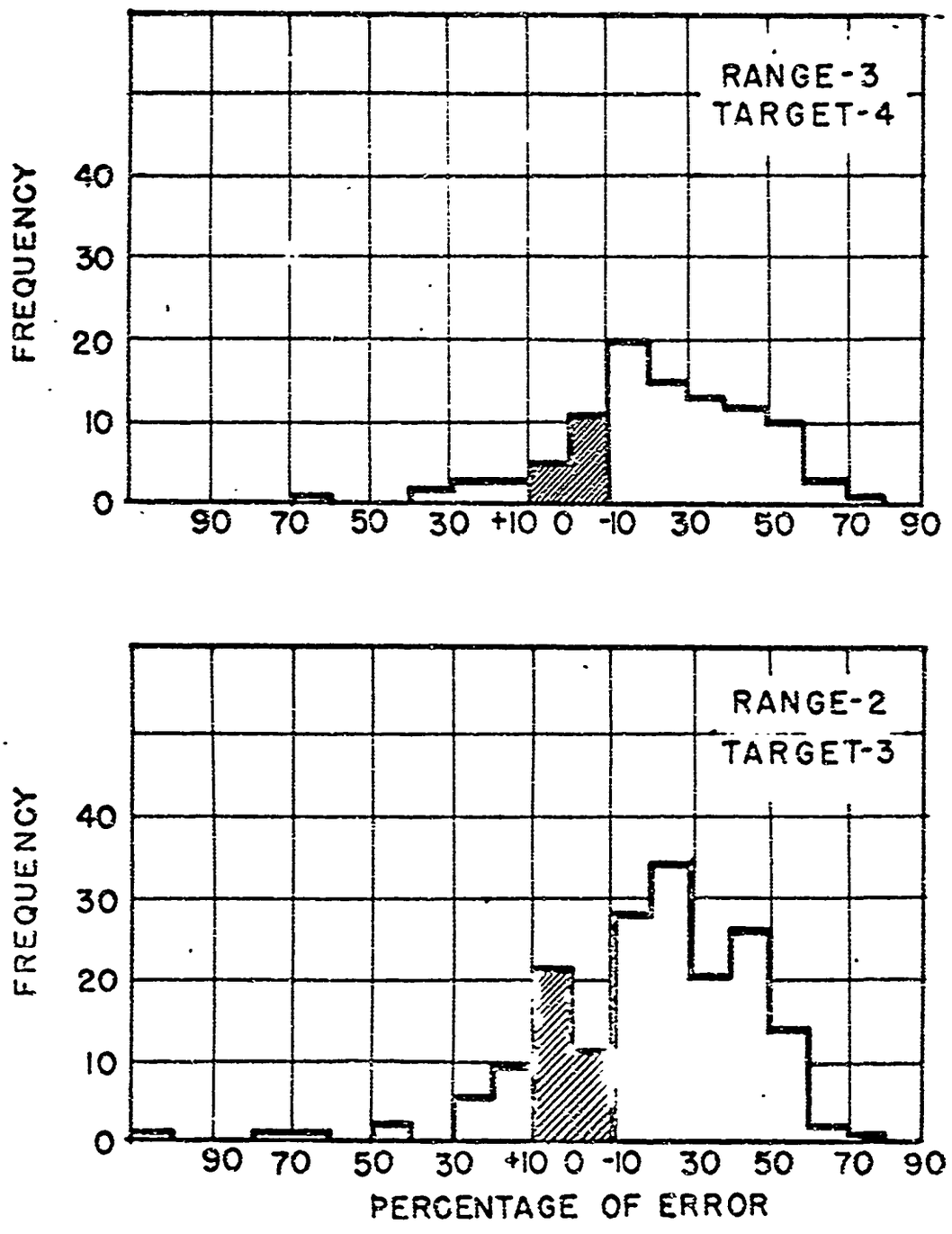
RANGE #1- 10 TARGETS - APPOX. 175 MEN

#2 10 TARGETS - APPOX. 175 MEN

#3-12 TARGETS - APPOX. 86 MEN

FIG. 3

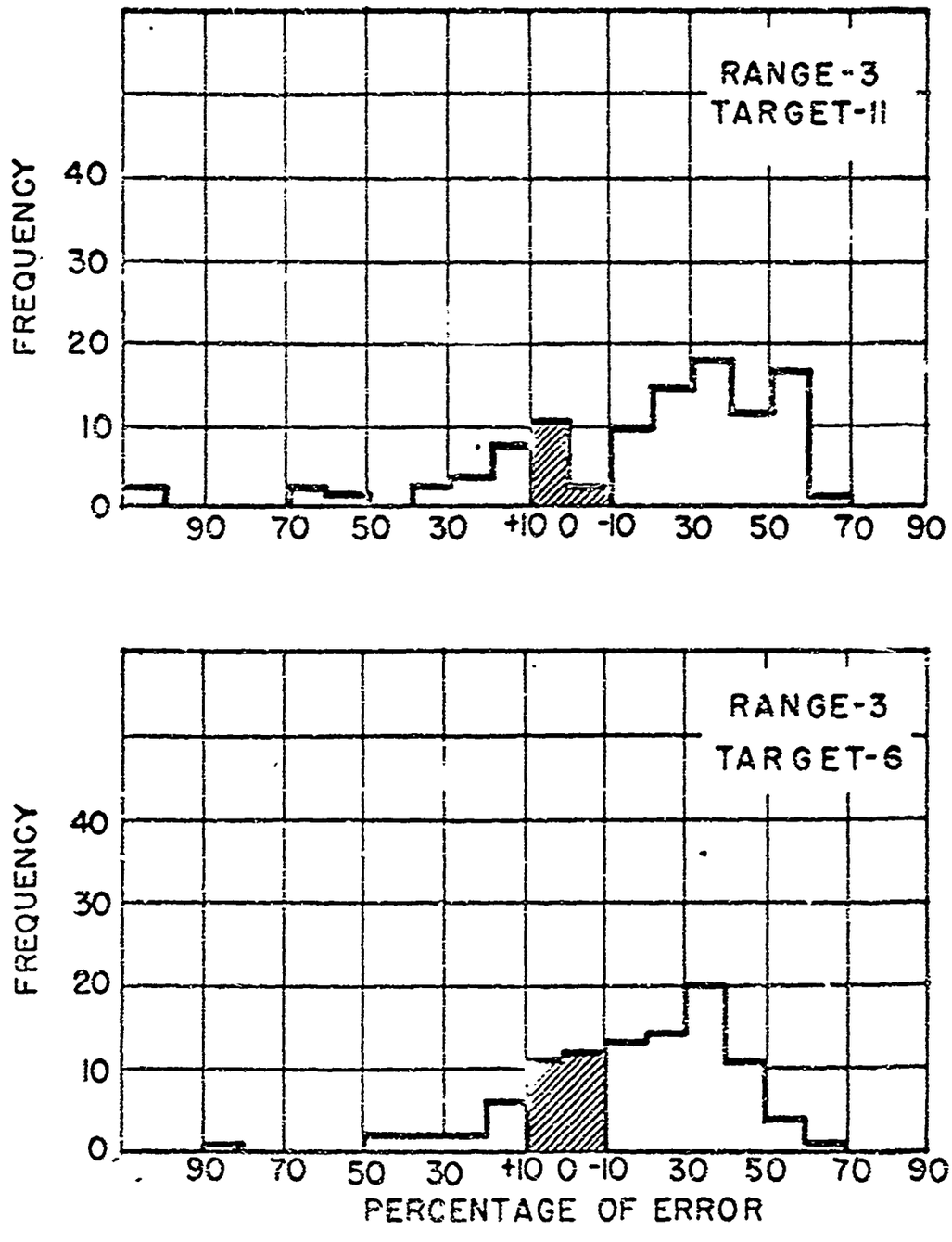
FIG.3-A



Encl. #4

FIG.3-A

FIG.3-B



Incl. #4

FIG.3-B

FIG.3-C

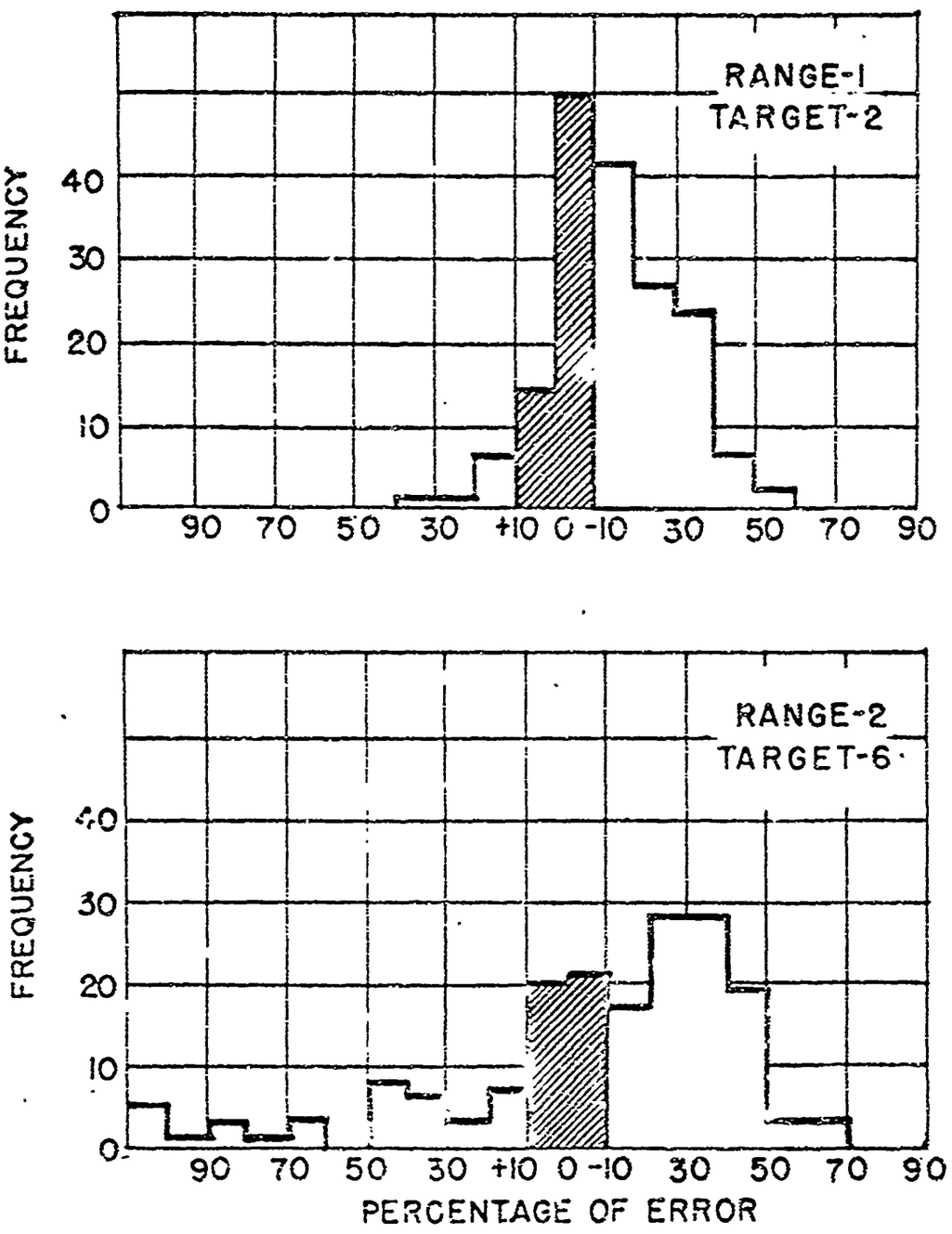


FIG: 3-C

Incl. #4

FIG. 3-D

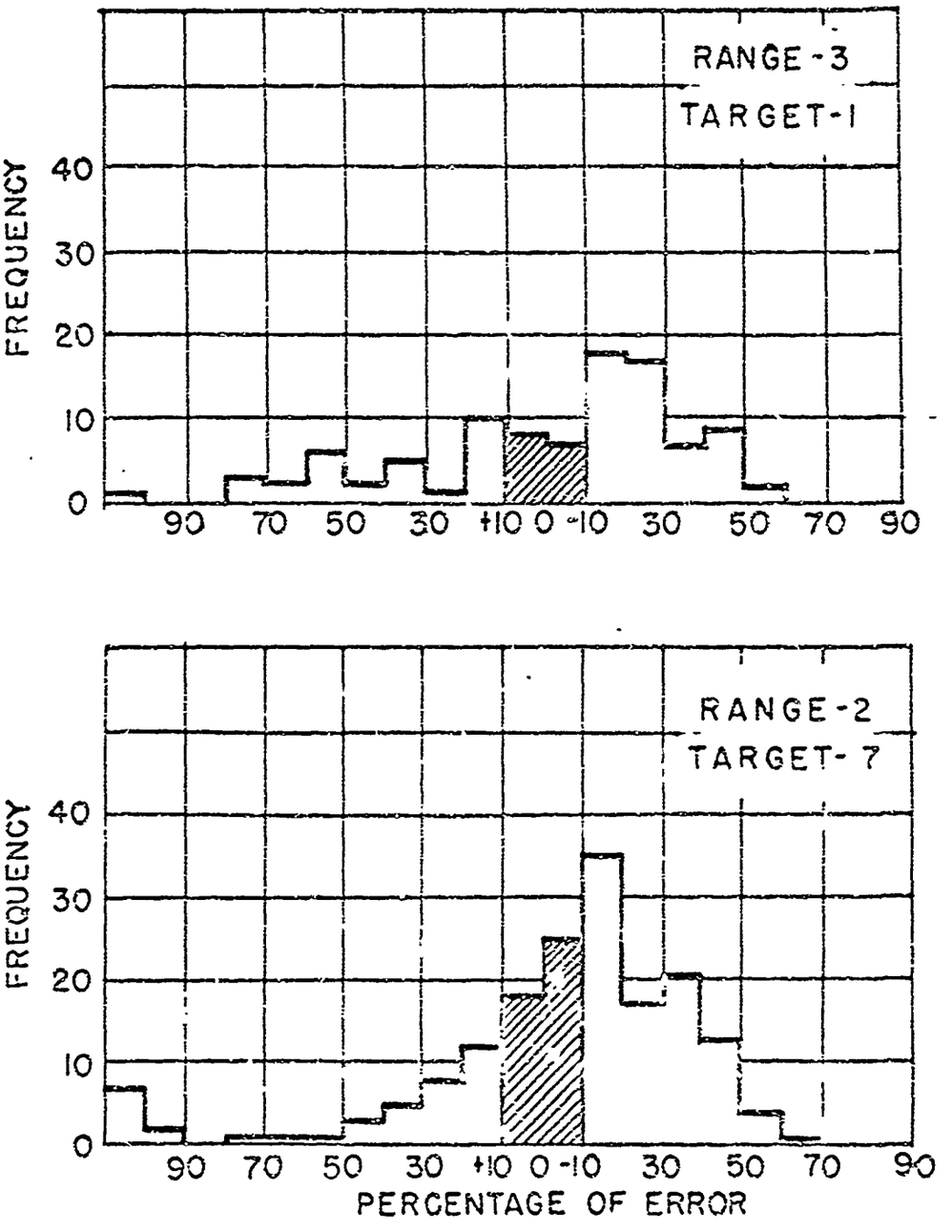


FIG. 3-D

Incl. #4

FIG.3-E

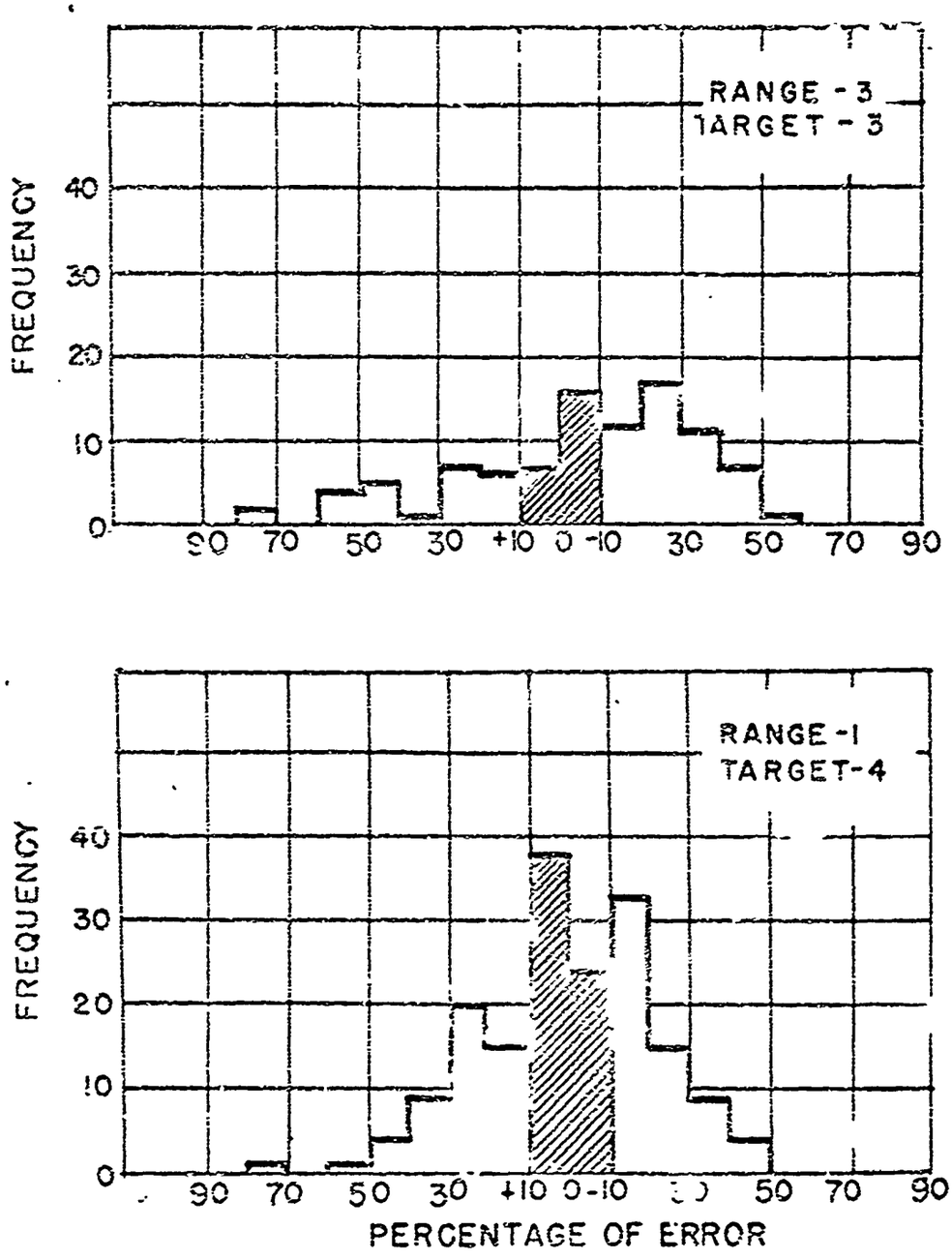
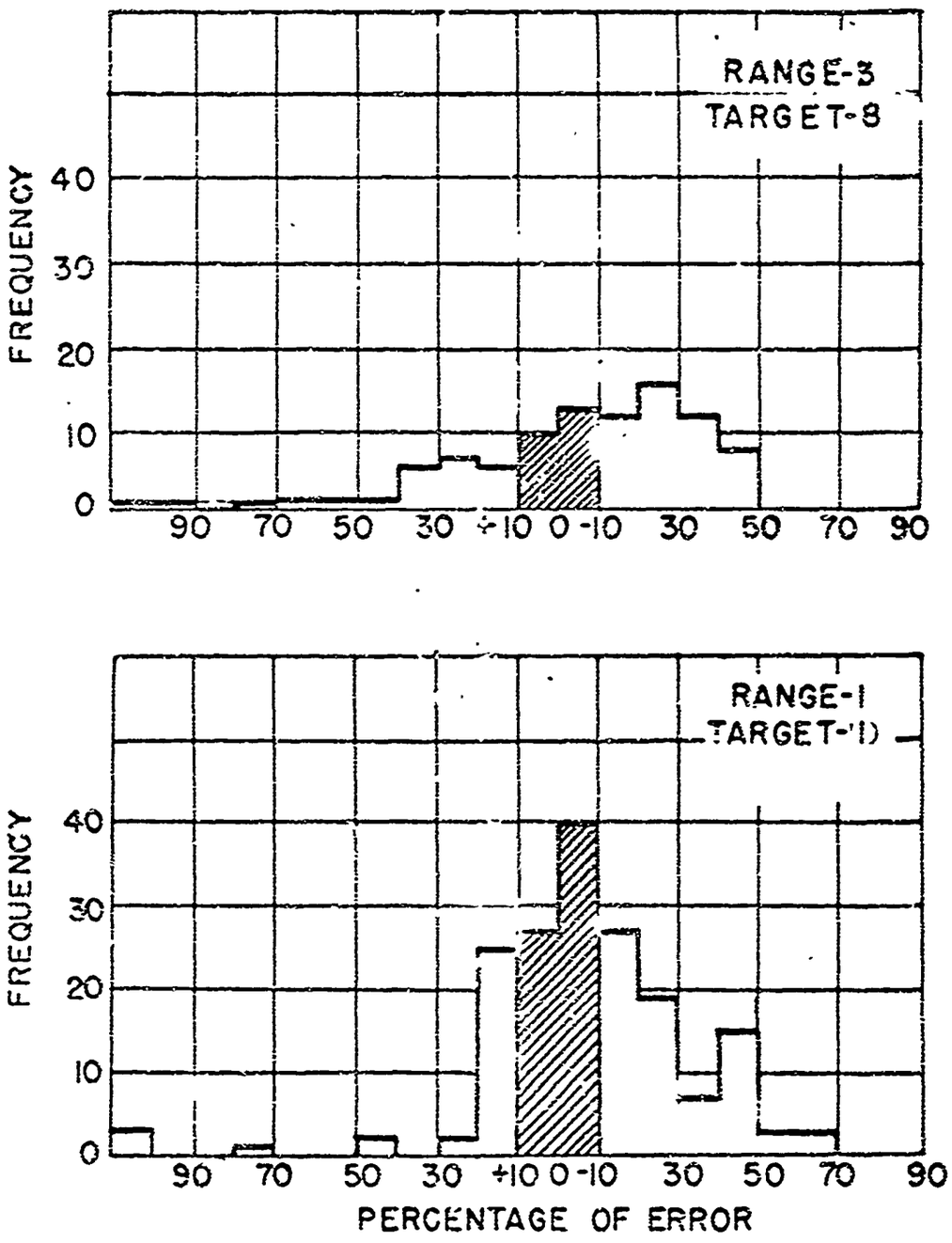


FIG. 3-E

Encl. #4

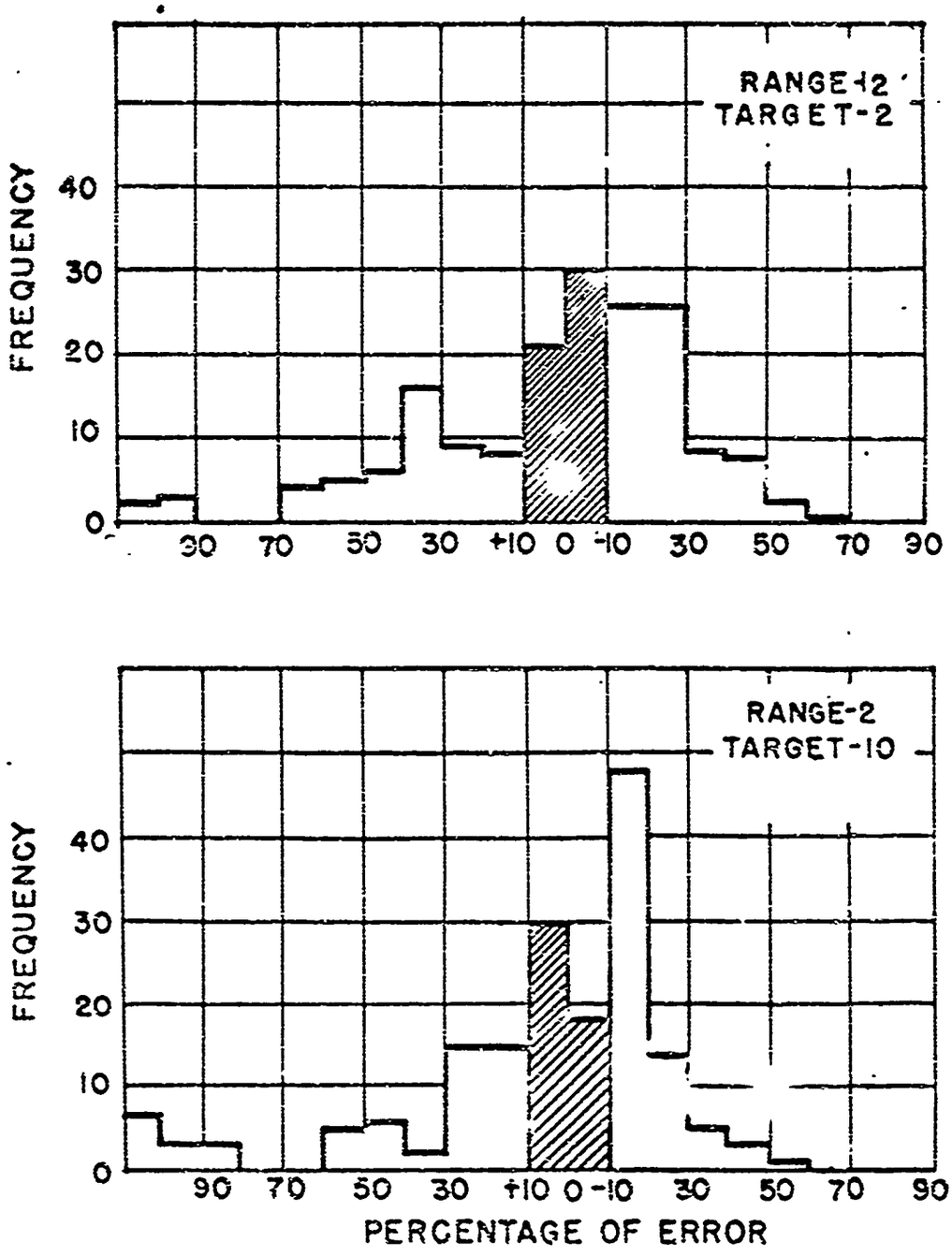
FIG. 3-F



Incl. #4

FIG. 3-F

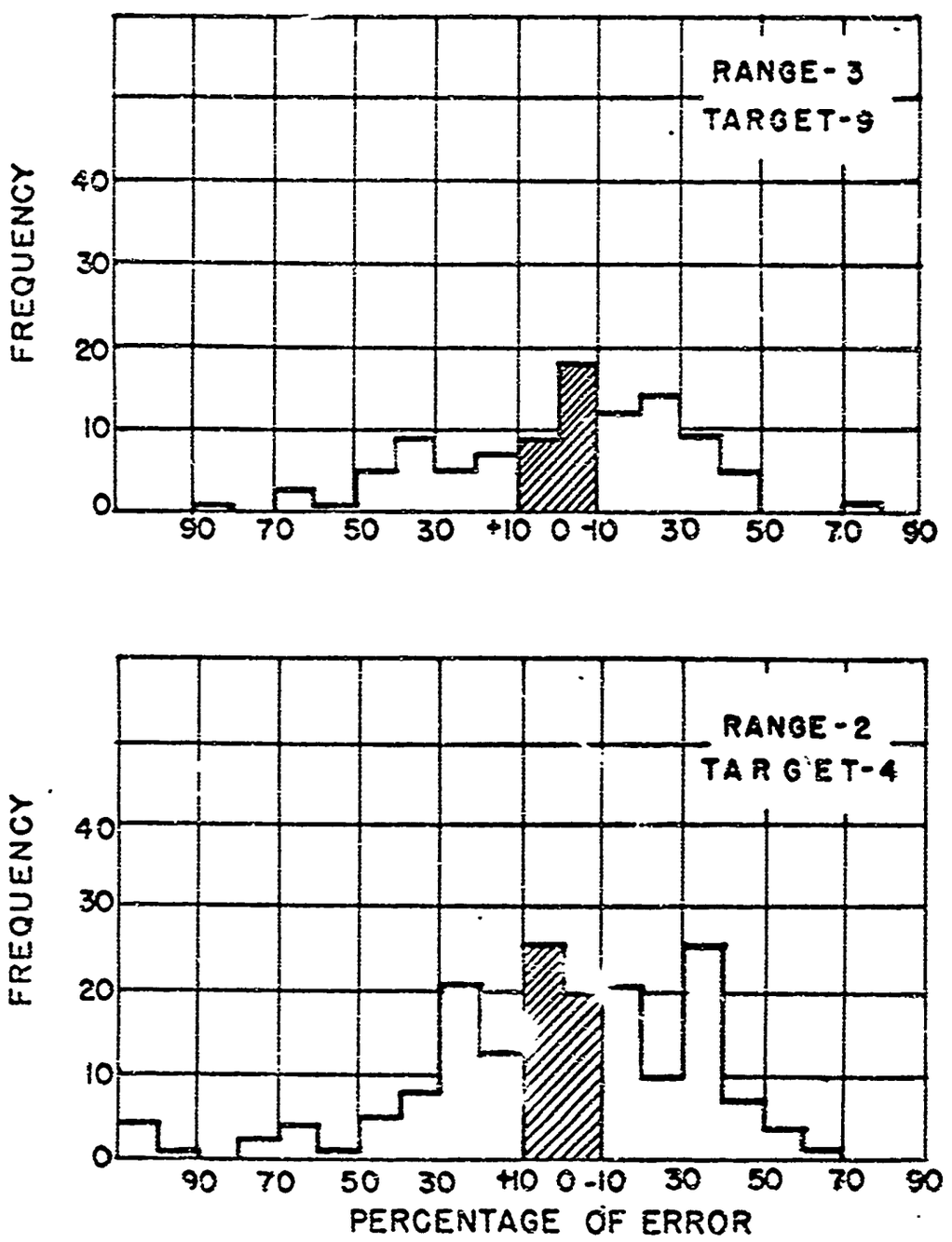
FIG.3-G



Incl. #4

FIG. 3-G

FIG.3-H



Incl. #4

FIG.3-H

FIG.3-1

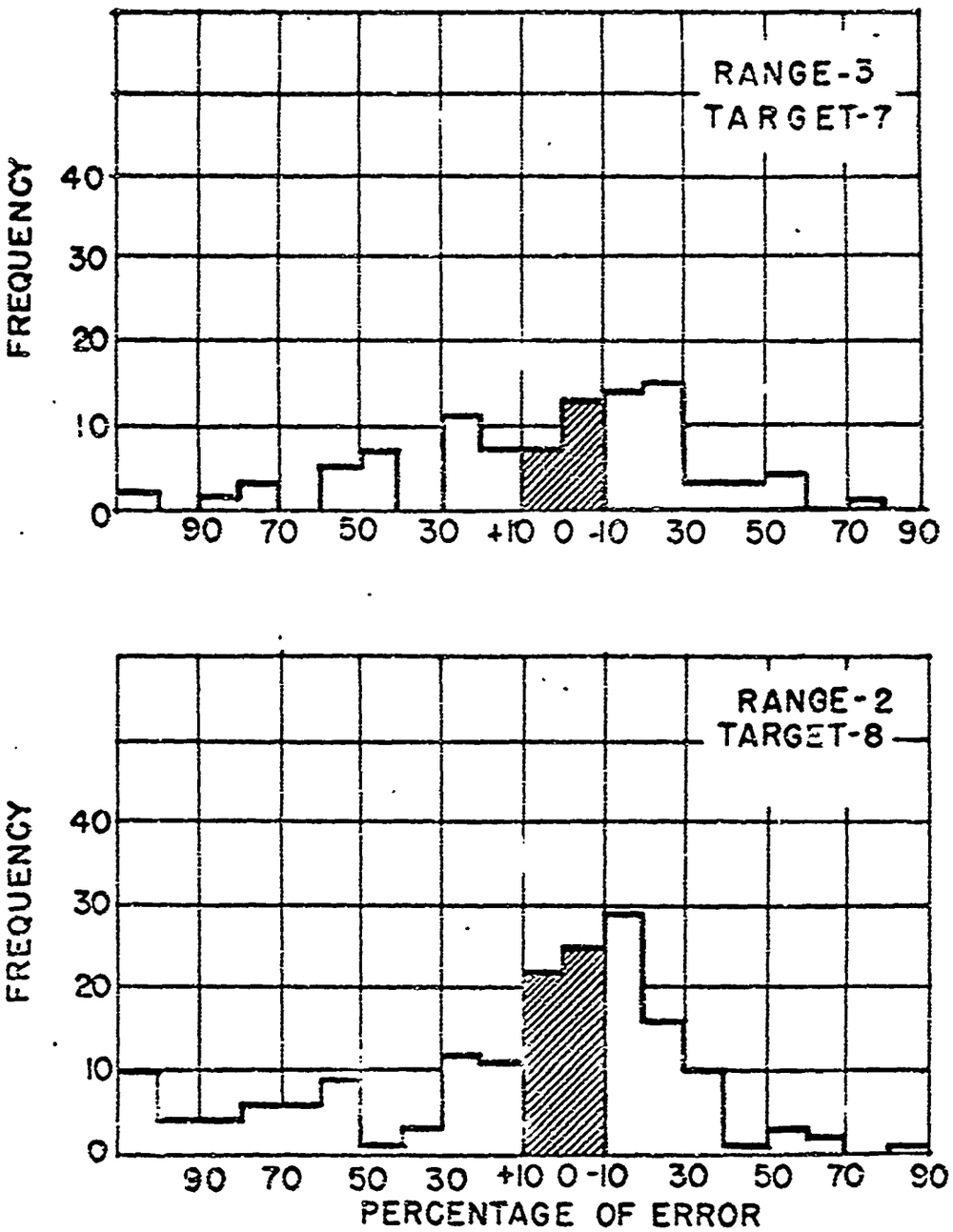


FIG. 3-1

Encl. #4

FIG. 3-J

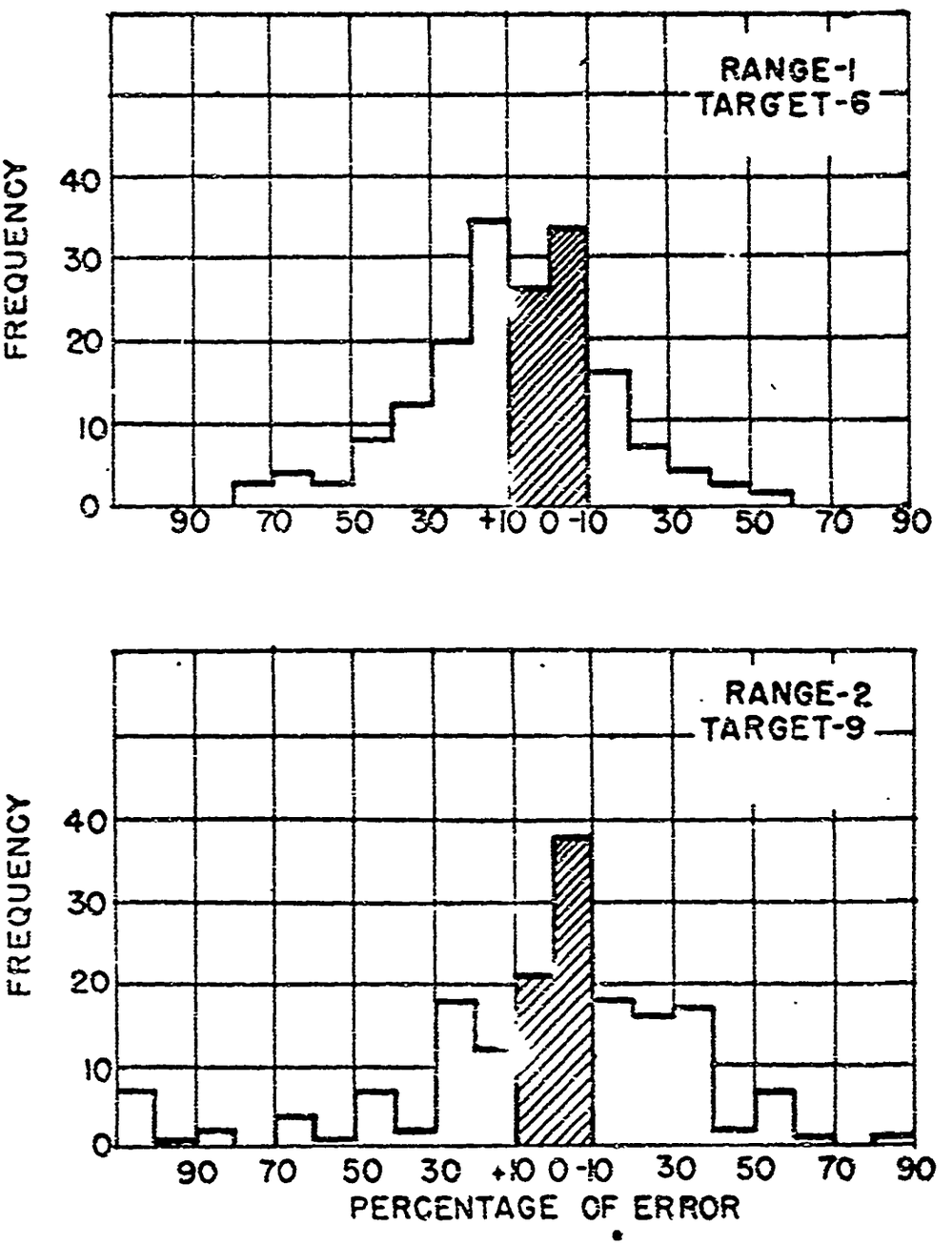
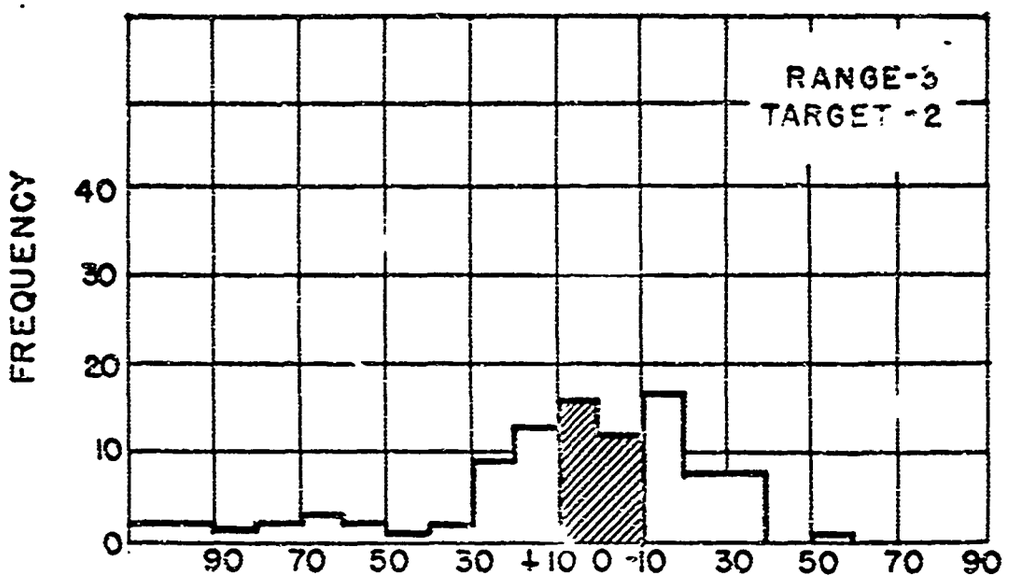
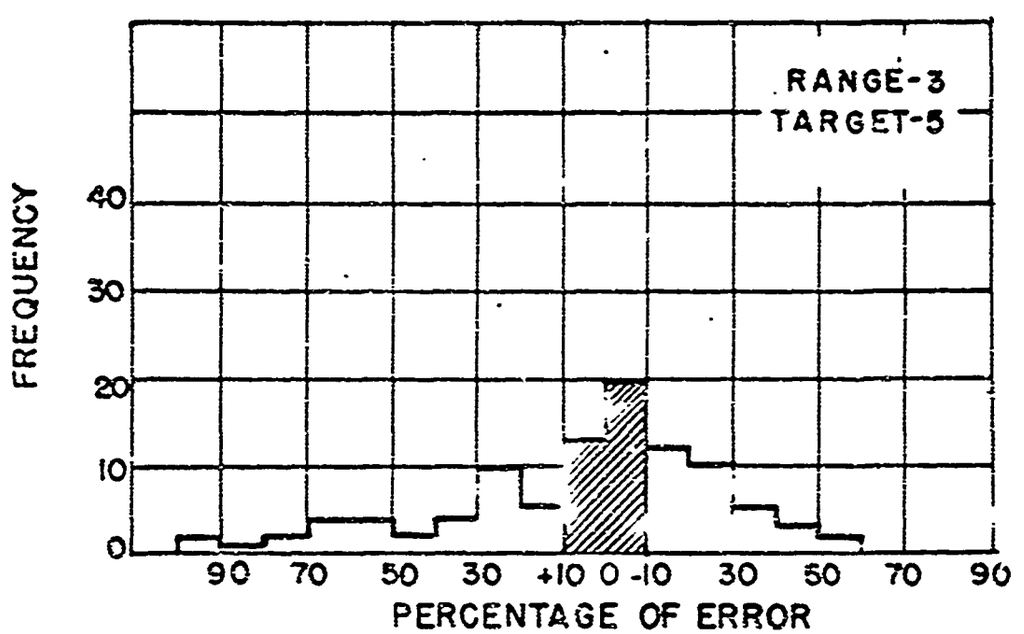


FIG. 3-J

Incl. #4

FIG. 3-K





Encl. #4

FIG. 3-K

FIG. 3-L

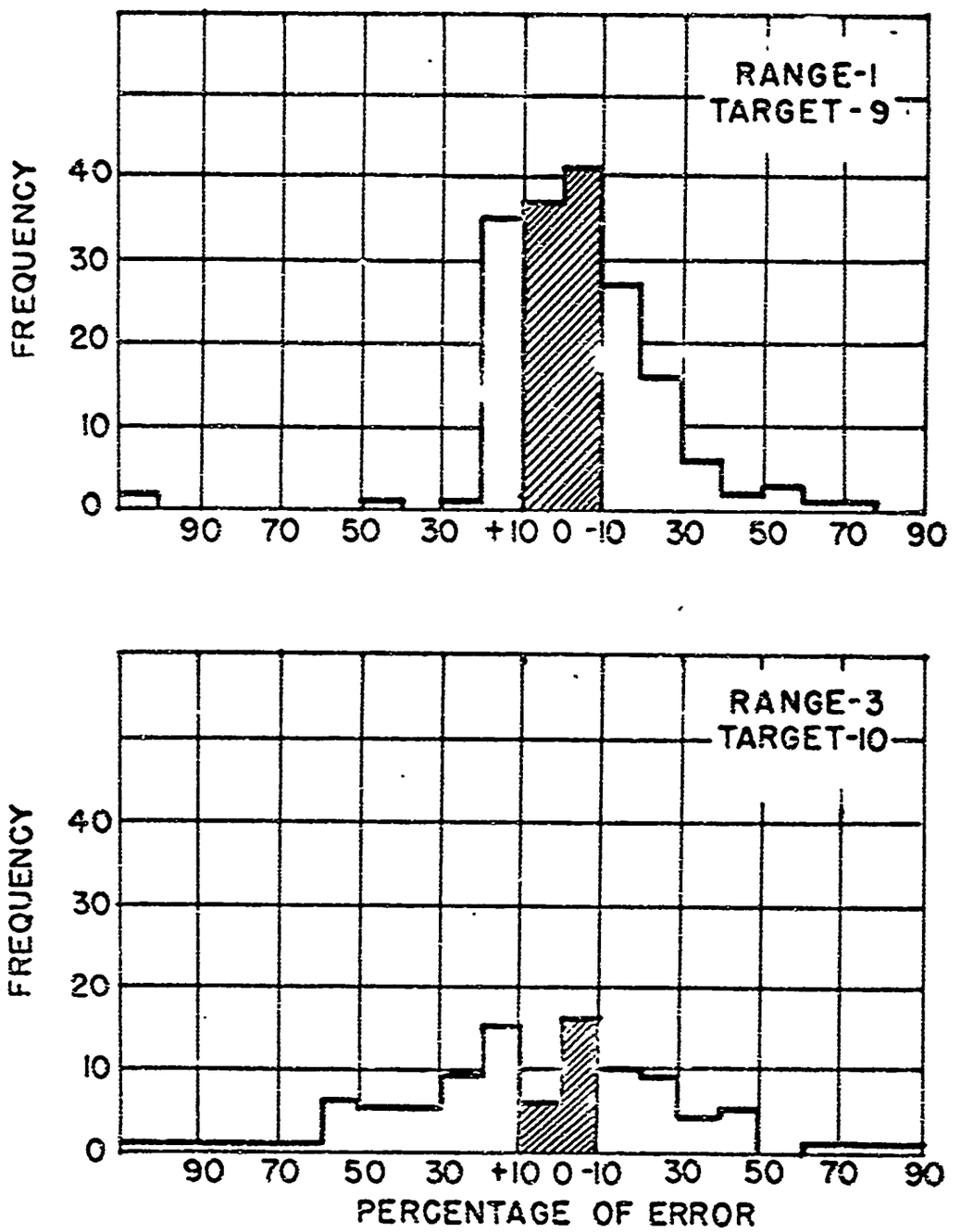


FIG. 3-L

Incl. #4

FIG. 3-M

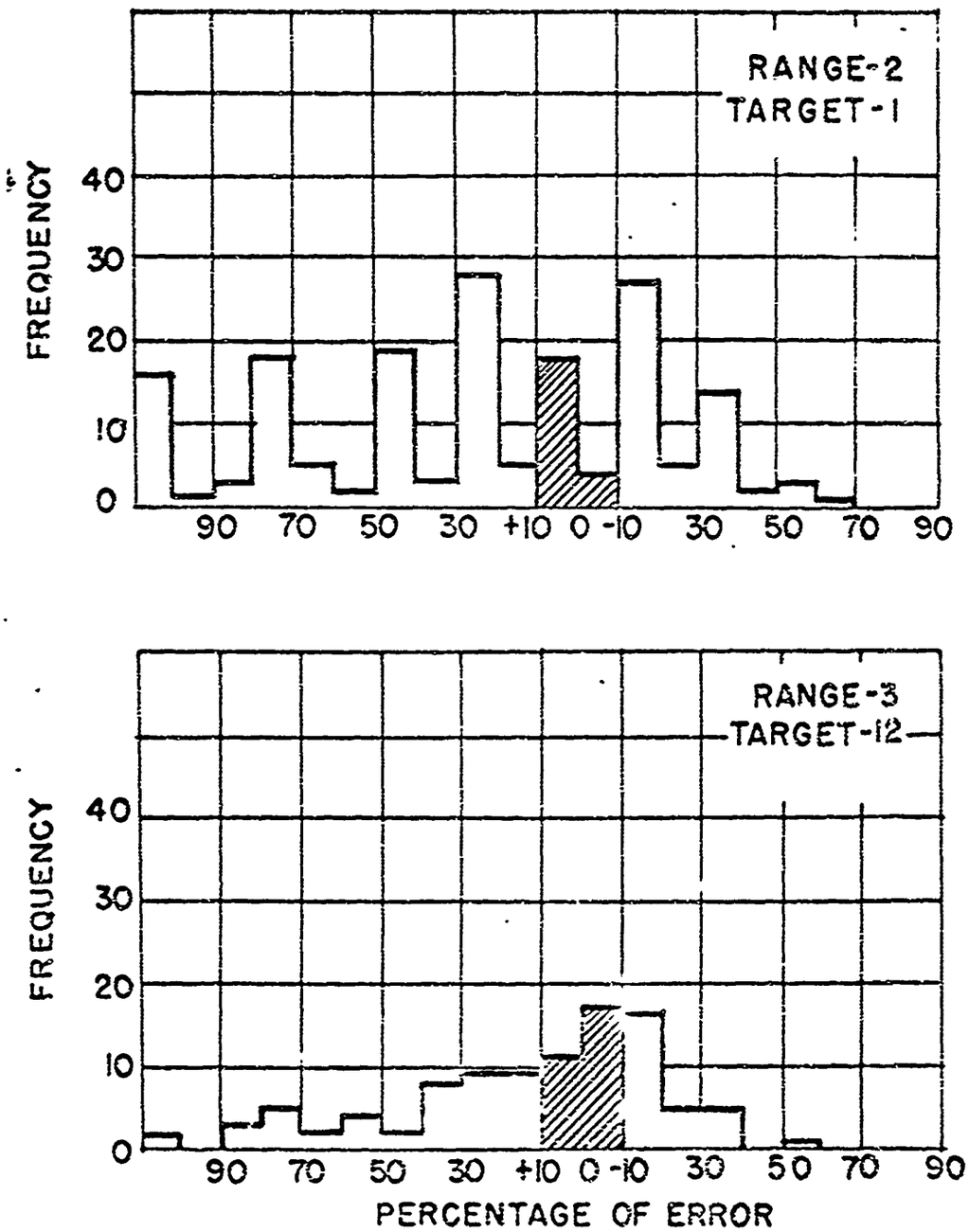


FIG. 3-M

Incl. #4

FIG. 3-N

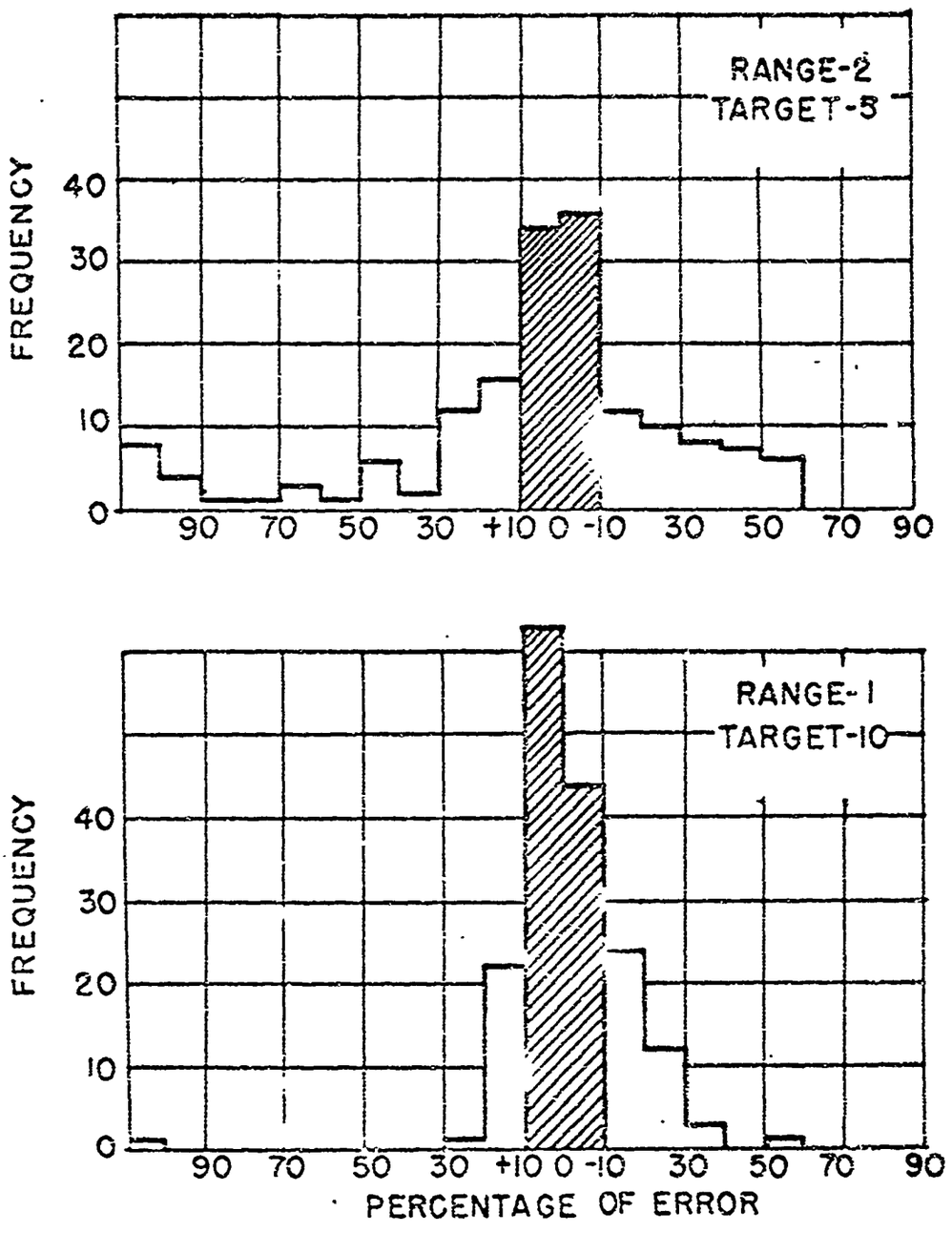
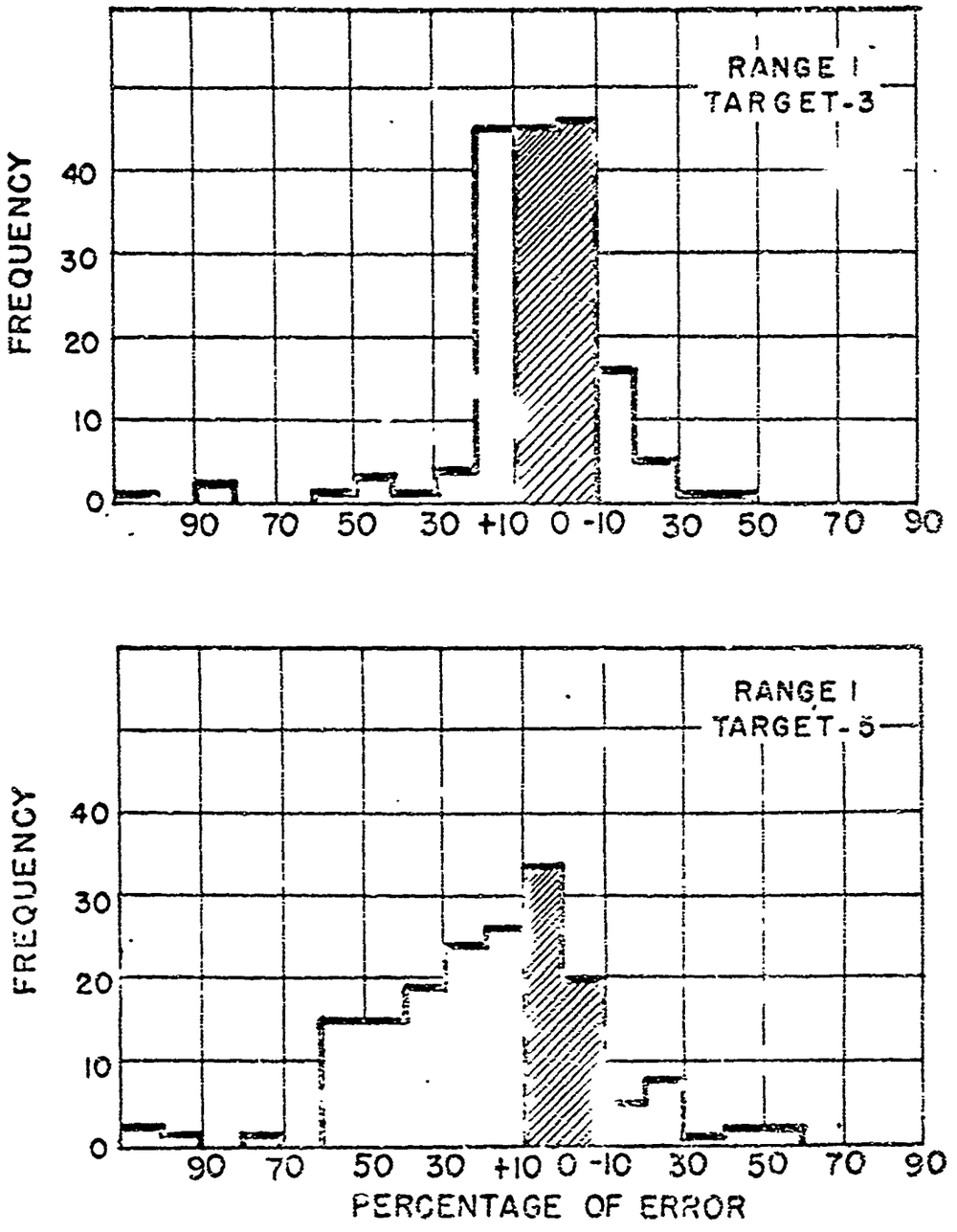


FIG. 3-N

Incl. #4

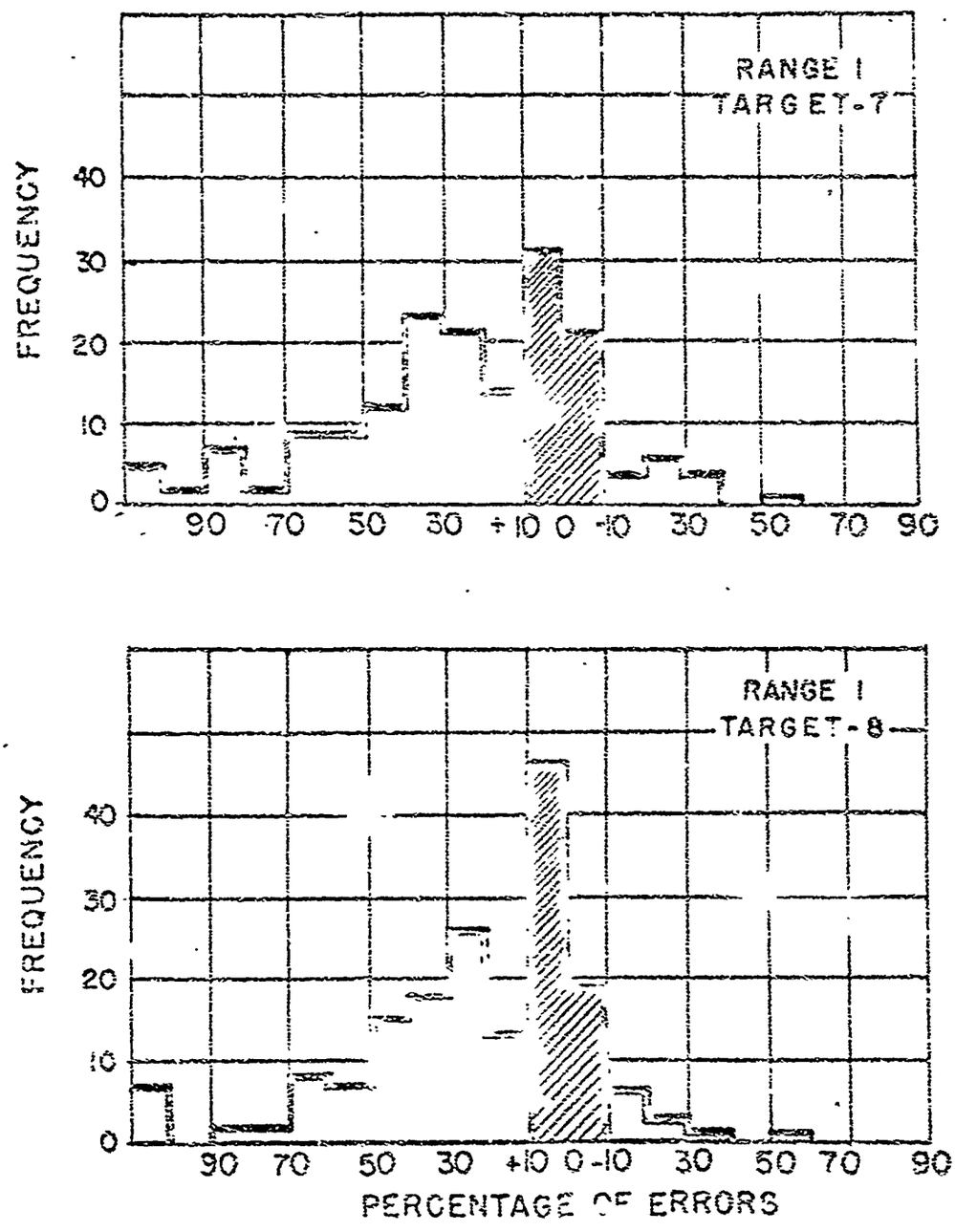
FIG.3-0



Encl. #4

FIG. 3-0

FIG.3-P



Incl. #4

FIG.3-P